MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ERT3036 – ADVANCED ROBOTICS

(RE)
(OPEN BOOK EXAMINATION)

2 MARCH 2018
3:00 p.m. – 5:00 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **5 pages** including cover page with **4 Questions** only.

2. Attempt **ALL** questions. The distribution of the marks for each question is given.

3. Please write all your answers clearly in the answer booklet provided.

Question 1

A differentially driven wheeled mobile robot is used as service robot for home and commercial users in Retail, Hospitality, Education, Healthcare, and Security areas.

(a) The wheel radius of Robot is 6 cm. The two wheels are separated by 40 cm. For each complete revolution of the wheel, the quadrature encoder gives 360 pulses. q_1 and q_2 are the incremental encoder reading for wheel 1 (left wheel) and wheel 2 (right wheel) respectively. The coordinates of wheel 1 (left wheel) is resting at (0, 0) at t =0 with an orientation of ϕ = 0 radian.

(i) Calculate the pulses measured by q_1 and q_2 respectively when the robot is making a 30 degrees turn in the clockwise direction with an instantaneous radius of curvature, R_i = 8 m.

[4 marks]

(ii) Calculate the coordinates of point P which is the mid-point between the two wheels along the differential drive axis.

[6 marks]

(iii) The mobile robot will continue to rotate in the clockwise direction with an instantaneous radius of curvature, R_i = 10 m. Find the ratio of the wheel velocities, v_2/v_1, where v_1 and v_2 are the linear wheel velocities respectively.

[3 marks]

(b) The Robot is located at point P with coordinates (5m, -3m) in the x-y coordinate frame with an orientation of 0 degrees with respect to the y-axis. Point P is the mid-point of the robot along its differential drive axis.

The goal position is located at point G with coordinates (0m, 0m). The width of the mobile robot, w is 0.4 m and the length, L is 0.6 m. A circular obstacle with a radius of 0.5m is located at point T (3 m, -2 m).

You will use Artificial Potential Field method to perform obstacle avoidance.

(i) Find the orientation of vector PG (with respect to the y-axis and clockwise being defined as positive).

[3 marks]

(ii) Design a potential vector U which is repulsive to the mobile robot. State all your assumptions.

[9 marks]

Continued ...

Question 2

(a) A 5-link biped robot in frontal plane is shown in **Figure Q2(a)**. Each link is modeled as a point mass at the centre of mass of the link.

(i) When the biped robot is standing using one leg, the zero moment point (ZMP) is located at position y_{ZMP} in the y-z plane. Express y_{ZMP} as a function of point mass (M_1 to M_5) and distance of point mass from the z-axis (y_1 to y_5 and $y_1 = y_2$).

[5 marks]

(ii) Discuss whether y_3 should be at the left of the ZMP or to its right when M_1 and M_2 are vertical along the z-axis.

[4 marks]

(iii) If M_3 also represents total upper body mass, modify the equation found in part (i) to include the acceleration in the y-axis for M_3 , $\ddot{y}$, when the biped robot is walking (ie switching legs).Z_c is the height of M_3 from the ground.

[4 marks]

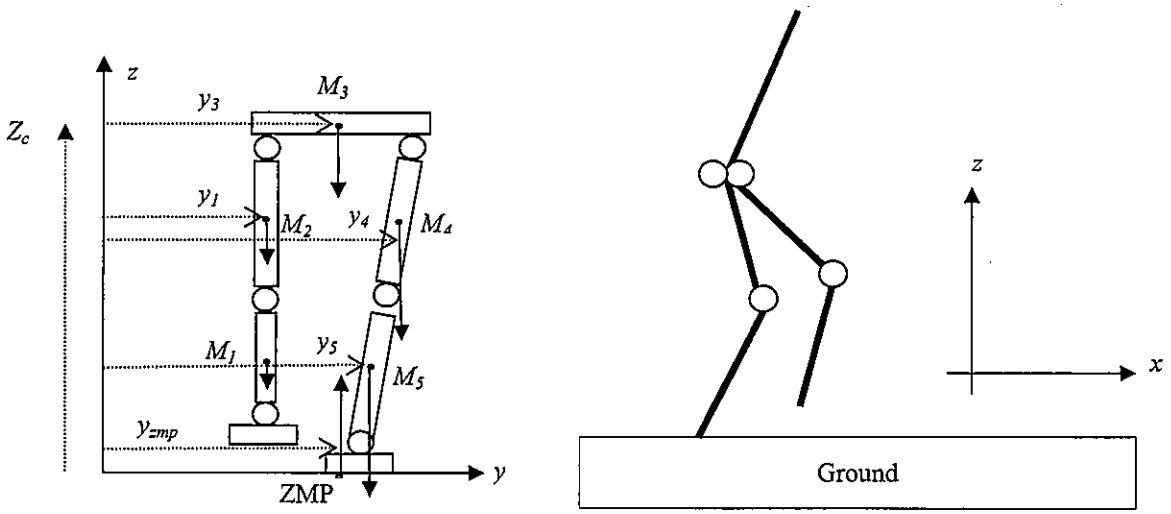

Figure Q2. A model of 5-link robot in **(a)** frontal plane and **(b)** sagittal plane

(b) The five-link biped robot is represented in the sagittal plane as in **Figure Q2(b).** Describe the mathematical steps to be taken in deriving its dynamic equation.

[12 marks]

Continued ...

Question 3

A quadrotor is resting on a flat ground. It will take off and hovers at a height, z_h and then moves in x direction for a distant x_f, before landing on the ground again as shown in **Figure Q3**.

(a) Describe a strategy to control the 4 rotors from take-off to hovering.

[9 marks]

(b) Describe how to rotate to a pitch angle of 30° without dropping from its hovering height, z_h.

[7 marks]

(c) For each motor on the quadrotor, the lifting force in is $F_i = 6\times10^{-8}\omega_i^2$ N where i is from 1 to 4; and ω_i is the angular rotation of motor-i in rounds per minute (rpm). When the quadrotor is flying in x-direction at a constant height with M = 0.5kg, $\phi = 30^\circ$, $F_1 = 1.1F_3$ and $F_2 = F_3 = F_4$, find ω_3 and $\ddot{x}$.

[9 marks]

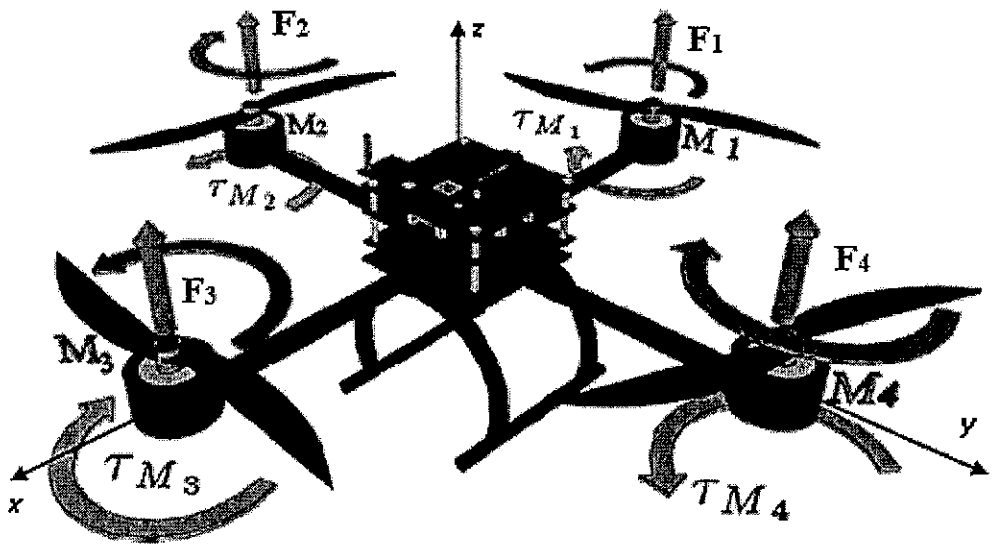

Figure Q3. A Quadrotor Model with its Lifting Forces

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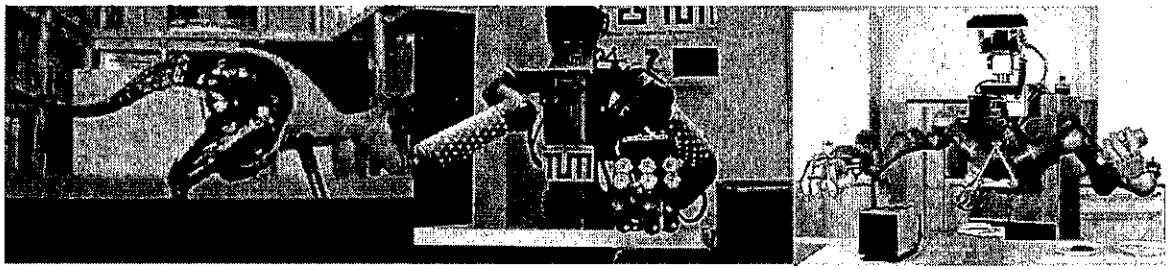
Question 4

(a) **Figure Q4.(a)** shows 3 advanced robotic systems. Give a brief description for each of the mentioned robotic system.

(i) BionicKangaroo **[4 marks]**

(ii) TOMM **[4 marks]**

(iii) PR2 **[4 marks]**



(i) (ii) (iii)

Figure Q4.(a). Advanced robotic systems in 2016

(b) A robotic micro mouse is exploring a 4×4 square maze as shown in **Figure Q4.(b)**. **J** is the destination square. At each square, the robot can only move at 4 directions (or less) but not diagonally. The only reward is $R = 100$ when the robot makes a transition from **K** to **J** and when it stays at **J**.

(i) Construct a graph for this mission. **[6 marks]**

(ii) If α (learning rate) = 0.6 and γ (discount rate) = 0.4, find the Q values of J after **Episode 1** and **Episode 2** respectively.

Episode 1: L to K to J and stays at J

Episode 2: P to O to K to J and stays at J **[7 marks]**

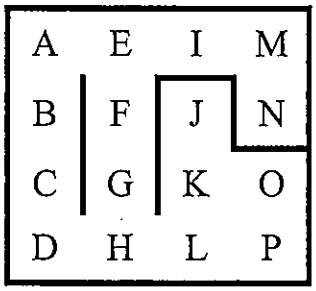


Figure Q4.(b). A 4×4 Maze with Solid Line Indicating Walls

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